Tidal Electric Limited

Feasibility Study for a Tidal Lagoon in Swansea Bay

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Executive Summary

Tidal Electric Ltd. (TEL) instructed Atkins Consultants Limited (Atkins) to develop their (TEL's) conceptual design for a tidal lagoon into a scheme design including an outline design for the civil engineering works, performance and functional specifications for the mechanical and electrical works. Atkins were to investigate the feasibility of construction, operation and eventual decommissioning of the tidal lagoon installation. This work was to include confirmation of annual electrical output and an estimation of capital and operating costs.

Agreed Design Basis

The design basis was generated in conjunction with TEL using the design concept contained within their terms of reference and other data provided by TEL including a report from ABPmer on the conditions in Swansea Bay; a report on output from Montgomery Watson Harza, hydrologic consultants, and the design/optimisation study from a similar tidal lagoon concept at Fifoots bay.

In particular TEL identified:

- An impoundment of total area of approximately $5Km^2$ predominantly in water depth of 1-5 metres at mean low water springs (MLWS). During the feasibility study three alternative impoundment layouts were also considered.
- Bi-directional generation turbines
- Installed hydro-turbine capacity of 60MW

Findings

The technical feasibility of the concept design has been confirmed. An electrical output of 60MW and annual generation of around 187,000MWh has been estimated for a $5Km^2$ total impounded area tidal lagoon concept under the conditions stated in the main body of the report.

Investigation of Site Conditions

Site conditions were established by means of a literature search and desk studies and tied into the report from ABPmer. It was found that:

- Mean tides vary on a lunar cycle between 1m and 9.5m above chart datum (the lowest astronomical tide). The mean tidal range between successive low and high tides ranges between a neap tide range of 4.1 metres and a spring tide range of 8.5 metres. These ranges determine the annual power output of a given design of tidal lagoon.

- An extreme water level, caused by a combination of tide and tidal surge, of 10.6m above chart datum can occur with a hundred year return (i.e. a frequency or probability of once every hundred years) based on current sea levels. Climate change predictions suggest that the level will increase to 11.1m. This is an essential design parameter for the turbine house, where flooding could cause significant damage to electrical equipment. The impoundment walls can be somewhat lower as no damage is caused by occasional overtopping.

- The Significant Wave Height (the mean of the highest one third of the wave heights at any one time) for a hundred year return period is estimated, from a range of sources, to be between four and six metres. This is the generally accepted criteria for engineering design and should be maintained for the turbine house design, for the reason stated above. The height of the impoundment walls is always a compromise between cost, longevity, ongoing maintenance and risk of catastrophic failure.

- The total settlement of civil structures laid on the seabed has been estimated to be between 0.3 at best, and 2.3 metres at worst (although the is flexibility in the plan layout to enable the final design to minimise the amount of impoundment built on the more marginal terrain). This determines the amount of extra height required to be built into the impoundment walls and identifies that special measures (e.g. piled foundations) might be required to prevent movement of the turbine house structure.

- An appropriate layout of the tidal lagoon will ensure that no unacceptable hazards are introduced to shipping using the navigational channels in Swansea Bay.

Findings

In summary, the study has indicated no exceptional problems inherent in the proposed scheme with regard to ground conditions, met-ocean environment or hazards to shipping at the proposed site.

Engineering Studies

The operating parameters for the Swansea Bay tidal lagoon have been modelled by Montgomery Watson Harza using a power simulation model. Parameters relating to the size of the lagoon, installed generation capacity, operating hydraulic head range and hydraulic losses have been used to determine the annual generation and load factor.

The operating conditions identified in the design basis indicate the suitability of low-head propeller type turbines of the bulb or pit design. The size and number of these conventional hydro-turbines was evaluated considering the following criteria:

- Fewer larger hydro-turbines are likely to be cheaper in terms of mechanical and electrical equipment supply and may incur lower civil works costs.

- The hydro-turbines require a minimum submergence in the tail-race to prevent mechanical damage during operation.

- Dredging a channel to accommodate larger hydro-turbines would need to be cleared from the planning viewpoint and may introduce silting and hydro-turbine erosion issues increasing operating/maintenance costs

A reinforced concrete turbine house has been designed comprising six modules fabricated on-shore and floated out to site and placed on a piled support. Each module will have a plan area of circa 40metres length and 30metre width. External (sea) chambers have been designed to abut the turbine house. The purpose of the outer chamber is to act as a stilling pond and to house protective screens preventing large objects from being ingested by the hydro-turbines.

The size of the impoundment structure and the volume of construction materials required results in this structure dominating the costs of the overall scheme. Various options for the impoundment wall were considered and the rubble mound construction identified at concept design confirmed as the most suitable and cost effective option.

A suitable electrical system for the tidal lagoon has been designed. It is anticipated that the generators will operate at a voltage of 11kV and that this will be stepped up to 132KV for the export line to shore. An auxiliary LV distribution system of 2.5MVA is anticipated to supply local lighting and power and control systems. The export line will be connected at 132KV to the utility Western Power Distribution (WPD) grid.

Findings

Engineering studies have been undertaken which have confirmed that practical design solutions exist for all necessary structures and equipment. Outline designs or specifications have been prepared for the impoundment walls, turbine house, hydro-turbines, electrical and control installations. Practical construction methodologies have been identified for the major civil engineering works. It was concluded that it was practical to install 24 turbines of 2.5MW capacity with runner diameter in the region of 3.3 metres. The annual output of the scheme (from hydro-turbines with a mean efficiency of 85%) will be circa 187,000MWh/year for a 5Km^2 impoundment.

The issue of grid connection has been discussed with the relevant utility, WPD and a practical scheme developed. Confirmatory studies will be required at detailed design, but these are considered a formality with the proposed scheme.

Implementation Programme

A desk study has been undertaken to test the supposition that the time likely to be needed to implement a project of this size and complexity would be about 36months. This overall timeframe fits in well with the lead times identified with the manufacturers of the major mechanical equipment items such as the hydro-turbines.

Findings

Implementation timescales have been considered and a 36month construction programme looks practical.

Design and Construction Risk

Most of the design risk can be engineered out at the detailed design stage by means of suitable design, choice of materials of construction, suitable protective systems, ground investigations and so on. Certain risks remain, such as:

- Inclement weather during the construction period (delaying project and increasing construction costs).

- Settlement beyond that anticipated by the design (and ground investigations)

- The insertion of a large artificial breakwater within Swansea Bay will create major changes to the water circulation patterns within the bay. This may have significant impact upon patterns of erosion and deposition within the bay. To some degree. hydraulic modelling should be able to identify both the impacts and any required amelioration measures.

The inherent design of the impoundment creates a stilling pond in which suspended solids can settle. There is therefore risk of sedimentation and silting up of the impoundment pool. It is recommended that this be investigated as part of the hydraulic modelling required during detailed design.

Findings

Most of the design and construction risks can be engineered out during detailed design. There are some areas where the detailed design may expose effects that have an impact upon capital or operating costs. These include settlement of the impoundment walls, silting of the impoundment pool and modified patterns of coastal erosion and deposition within Swansea Bay. However, it is safe to say that most of the remaining construction risks are quantifiable, could be ascribed to external factors such as exceptional weather.

Maintenance

Maintenance of the impoundment walls is likely to require annual inspections followed by repair and replacement of elements displaced by tide or wave action. Additional inspections will be required following storm events.

Maintenance of the turbine house is likely to require annual inspections to identify any damage to the structure. Repairs will most likely be required to fixtures and fittings to the structure rather than to the structure itself.

Electrical equipment will require minimal maintenance. Annual inspections will be required for fans, pumps and battery/charger systems. Major equipment such as switchgear and control/relay equipment will typically require a three to five year inspection regime.

Maintenance of the turbine and generators is likely to require an annual inspection to check on seals, oil and mechanical clearances. A major outage of each unit is likely to be required every four years. The frequency of this major inspection will be dictated by findings in the annual inspection.

Findings

There is likely to be minimal regular maintenance required. Annual inspections of the main components of the tidal lagoon will be supplemented with specific machine outages at longer frequencies.

De-Commissioning

A study was undertaken to review whether there might be particular issues associated with the de-commissioning of this facility. It is assumed that the mechanical and electrical systems can be drained of fluids, cut up and removed for scrap/recycling. The civil structures can generally be left in place. If required, the impoundment structures can be partially dismantled in order to reduce flows through breaches in the impoundment (i.e. at the turbine house). If left unattended, it is likely that the area inside the impoundment walls would eventually silt-up and form a marshland.

Findings

Final de-commissioning presents no particular technical problems. It would be perfectly practical though expensive, due to the quantities of material involved, to entirely remove the impoundment walls. It is recommended that these be considered a permanent feature.

Costs

Investigations were undertaken with various suppliers and contractors to give an assessment of capital costs. These can only be indicative given that there was no competitive tender against a specific design, which will be the subject of the next phase of the development of the scheme.

Capacity (MW) 60

Load factor 36%

Costs:	£m
Impoundment	48.5
Turbine Hall structure	12.7
Turbine Plant and equipment	14.1
Maintenance equipment	0.1
Electrical Connections	3.0
Access Jetty	0.5
Navigation lights	0.1
Total	£79m
cost / installed MW capacity	£1.32m

In addition there will be costs of the detailed design; the Environmental Impact Study; the obtaining of planning consent and project management (which have been budgeted by TEL to cost £2.5m).

Findings

Initial cost estimates show that capital costs are of the order of £1.4m per MW of installed capacity with de-minimus running costs. TEL have estimated that amortising all the costs over the life of the equipment at an after-tax cost of capital of 8% this equates approximately to 3.5p/kWh.